N69-17467

NASA TECHNICAL MEMORANDUM

NASA TM X-53808

January 3, 1969

NASA TM X-53808

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EFFECTS OF WELD HEAT ON THE PROTECTIVE PROPERTIES OF CONVERSION COATINGS

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MSFC - Form 3190 (September 1968)

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ABSTRACT

A chromate conversion coating is applied to the Saturn V tank skin sections soon after fabrication. The elevated temperature resulting from subsequent welding processes considerably lowers the amount of corrosion protection afforded by this coating. A test program was conducted to evaluate the extent of coating degradation on 2219-T87 aluminum alloy and to investigate methods of repairing the degraded areas. The tests showed that the coating was damaged at temperatures exceeding 140°F or for a distance of approximately six inches from the weld. Mechanical removal of the damaged coating followed by a manually applied conversion coating treatment effectively restored the corrosion protection to the damaged areas.

Presented at the Air Force Materials Laboratory, 50th Anniversary, Corrosion of Military and Aerospace Equipment Symposiums, Denver, Colorado, May 22-25, 1967, and the ASTRA Conference on Corrosion Problems and Control, Kansas City, Missouri, September 13-14, 1967.

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PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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SUMMARY

The susceptibility of 2219-T87 aluminum alloy to surface corrosion necessitated the use of a conversion coating to provide some degree of protection during fabrication of the Saturn V skin components. In order to determine the extent of coating degradation resulting from weld heat during the joining processes, salt spray tests were conducted on sheet, plate, and skin configuration samples which had been subjected to both controlled heat treatments and actual welding processes. Results of these tests showed that temperatures in excess of 140°F (60°C) considerably reduced the amount of protection afforded by conversion coatings. The results showed also that the heat resulting from the welding processes would damage the coating for a distance of approximately 6 inches from the weld. The damaged areas could be effectively repaired by mechanically stripping the old coating and manually applying a concentrated conversion coating solution. It was demonstrated that a spray touch-up treatment, using a conventional solution, enhanced the protection of aged and abraded coatings.

INTRODUCTION

Aluminum alloy 2219-T87 is used as the major structural alloy for the first stage of the Saturn V vehicle. At the time of the selection of this alloy, it was recognized that the use of the material would be somewhat restrictive in some aspects, one of which is the low degree of resistance to atmospheric corrosion.

Since the 2219 material is an aluminum-copper alloy, it was expected to offer about the same degree of resistance to corrosive environments as other aluminum-copper alloys such as 2014 and 2024, which is of a lower order of magnitude than the lower strength alloys such as 6061. This indicated that some form of protection would have to be provided during fabrication and assembly of structural parts or other components used for the Saturn S-IC vehicle (FIG 1). Certain chemical surface treatments or conversion coatings have been very helpful in accomplishing this on various aluminum alloys; however,

initial tests comparing the corrosion protection offered the 2219 alloy by these conversion coatings indicated that they did not appear to improve the corrosion resistance to the extent that they do on other aluminum alloys. Although moderate protection was desirable, it was decided that a properly applied conversion coating would offer sufficient protection during the somewhat lengthy fabrication and assembly phases.

During the fabrication of the first test vehicle, several problems arose concerning the use of this protective coating. One area of concern was centered on the surfaces adjacent to the edges of large skin sections which had to be joined by welding. In order to produce satisfactory welds, the protective coating had to be stripped back away from the edges, and, after welding, the bared surfaces had to be recoated to prevent corrosion from occurring in these areas.

Since the heat from the welding process would be dissipated into areas adjacent to the welds (heat-affected zones), it was expected that some degradation of the protective coating would occur. Literature references stated that, when the coatings were exposed to temperatures in excess of 150°F (66°C), the normal water of hydration is driven off, and the chromate coating is changed from a soluble to a less soluble state. Thus, the chromate ion inhibitor is not as effective and the protective value of the coating is greatly reduced.

In order to fully evaluate the extent of coating degradation resulting from the welding process and to investigate methods of repairing the degraded areas, a test program was initiated using conversion coated 2219-T87 aluminum sheet, plate and skin configuration samples which were subjected to controlled heat treatment and also to a typical weld sequence. The conversion coatings used for these tests were conventional Iridite 14-2 and Alodine 1200 treatments. All corrosion tests were conducted in accordance with Federal Test Method Standard Number 151A using a 5 percent salt solution.

EXPERIMENTAL PROCEDURE

Since the design of the S-IC stage requires several different thicknesses of 2219 alloy, tests were conducted on material ranging from 0.1 to 1.0 inch thick. Test samples consisted of both flat specimens and sections cut from panels with the T-stiffener configuration (FIG 2). In all cases, tests were conducted on conventionally coated panels using either Iridite 14-2 or Alodine 1200 treatments. Surface preparation prior to conversion coating consisted of solvent degreasing, alkaline cleaning and a chemical deoxidation.

An initial examination was conducted on 0.5 inch plate material that had received an Iridite 14-2 coating. In conjunction with the welding procedure development on a test configuration, thermocouples were placed approximately 1-1/16 inches from the weld joint, then every 1-1/2 inches apart for a total distance of 7 inches. Temperature readings were obtained to determine the highest temperature reached during the welding process and the approximate time of exposure at various distances from the weld area. Specimens were then taken from this material which extended for 7 inches on each side of the weld. These samples were exposed to a 5 percent salt spray after solvent wiping to remove contamination.

After the preliminary tests outlined above, the use of thermocolor paints was employed in an attempt to establish the temperature at which degradation of the conversion coating was initiated. The thermocolor paints were used on 0.5 inch plate materials. Color changes were not as sharply defined as desired and this idea was abandoned in favor of using 4-inch by 6-inch by 0.100-inch panels and exposing them to controlled temperatures for a specified time. Several panels were coated with either Iridite 14-2 or Alodine 1200 and were subjected to heat treatments either immediately, after aging 3 days, or after aging for 2 months. Duplicate panels of each coating were exposed to temperatures ranging from 120°F (49°C) to 350°F (177°C) in a forced air oven for either a 15 or 30-minute period. After coating, the panels were subjected to the 5 percent salt spray test.

Following these tests, two plates of 0.375 inch flat material, 18 inches by 21 inches, were conversion coated and welded. Sections of this material were taken for salt spray tests and evaluations. Large panels having the T-stiffener configuration of the Saturn V tank skins were then obtained with edge thicknesses of 0.23, 0.50, and 0.87 inch. These panels were conversion coated with Iridite 14-2 and welded in the same manner as the skin components. Sections of these panels representing all weld thicknesses were also subjected to the 5 percent salt spray.

In addition to tests to determine the heat degradation of the conversion coatings, studies were also conducted to establish the most effective method of repairing the heat damaged areas. All specimens used for these tests were cut from tank skin segments or 1/2-inch plate material which had been conversion coated prior to welding. Each specimen had a weld area and adjacent heat-affected zone. Since the coating repair would have to be made on completed tank sections, manually applied treatments were the only method evaluated. See Table I.

EXPERIMENTAL RESULTS AND DISCUSSION

An examination of the data recorded during the welding of the initial 1/2-inch plate material indicated that a temperature of approximately 480°F (249°C) was reached at a distance of 1-1/8 inches from the weld edge, and at a distance of 7 inches the temperature was 200°F (93°C). Since literature references stated that temperatures exceeding 150°F (66°C) are detrimental to the corrosion protective mechanism of the coating, the data recorded indicated that the coating on this panel was probably damaged for a distance of approximately 7 to 8 inches. Sections cut from this panel were placed in a 5 percent salt spray, and, after 7 hours of exposure, considerable corrosion was observed over the entire surface (FIG 3). These sections were 15 inches wide with a weld in the center. From these tests the indication was that approximately 7 inches or more from the weld would need to be repaired in order to provide satisfactory corrosion protection to this area (FIG 4).

Results obtained in salt spray tests of the 0.5 inch welded material indicated that data were needed to ascertain the degree of coating degradation that could be expected after exposure to specific temperatures for short periods of time. Since this type of information could be obtained with laboratory controlled tests, duplicate panels 4 inches by 6 inches by 0.100 inch were coated, subjected to a heat treatment and exposed to the salt spray. In these tests, regardless of coating, heat exposure time or aging, all panels subjected to temperatures of 180°F (82°C) or greater had light corrosion over the surface after exposure to the salt spray for 24 hours (FIG 5). The corrosion increased rapidly with additional exposure time. Panels subjected to a temperature of 160°F (71°C) were somewhat less affected, and the corrosion did not progress as rapidly as panels exposed to higher temperatures. Panels exposed to a temperature of 140°F (60°C) were only slightly affected (FIG 6), and additional exposure to the salt spray did not result in a substantial increase of corrosion (FIG 7). The Iridite 14-2 coatings appeared to have a slight advantage over the Alodine 1200 coatings at a temperature of 140°F (60°C); however, both coatings provided protection similar to coatings which had not been subjected to the heat treatment. The coatings did not appear to be affected appreciably by exposures to 120°F (49°C) (FIG 8) which was further demonstrated when the salt spray exposure was extended to 168 hours (FIG 9). No appreciable difference was noted on the unaged and aged panels, and exposure to the heat treatment for 15 minutes was almost as detrimental as a 30-minute heating. Long periods of exposure (2 hours) at a temperature of 150°F (66°C) proved almost as serious as short exposures at higher temperatures (FIG 10).

In the tests where sections of the 0.375 inch welded plate material were exposed to the salt spray, considerable corrosion had occurred 4 to 5 inches from the weld after only 24 hours of exposure, while only light corrosion had occurred on the remainder of the sections after 168 hours of exposure.

Since the large panels used for the final test were of the T-stiffener design and were conversion coated and welded by production fabrication personnel, the results were expected to be more indicative of the coating degradation on Saturn structural assemblies. Sections 6 inches wide and extending out from the weld for 22 inches were cut from each large panel representing all weld and skin thicknesses of the Saturn tank assemblies. After 7 hours of exposure to the salt spray, some corrosion was noted extending outward from the weld. After 24 hours of exposure, considerable corrosion was noted in the heat-affected zone of each panel. This heavy corrosion extended to 3 to 4 inches from the weld on the 0.23 inch thick panel and 5 to 6 inches on the panels 0.5 and 0.87 inch thick (FIGs 11, 12, and 13).

Since the amount of protection afforded by the conversion coating was reduced to a great extent in the heat-affected zones, most of the repair methods evaluated offered some improvement in the corrosion resistance. The most effective treatment involved the removal of the damaged coating by some mechanical means and reapplying the coating with a sponge or spray treatment. By increasing the concentration of the coating solution two or three fold over that of a regular immersion bath, the effectiveness of the treatment was such that the corrosion resistance of the repaired area was equal to or greater than that of the original coating (Table I).

CONCLUSIONS

Results from the above tests show that exposure of a chemical conversion coating to temperatures in excess of 140°F (60°C) seriously affects the amount of corrosion protection afforded the aluminum surfaces. The results also showed that the heat from welding processes would damage the coatings for a distance of approximately 6 inches from the weld. Although all of the repair techniques evaluated offered some improvement in corrosion protection, satisfactory protection was not obtained until the damaged coating had been removed and a new coating applied. An additional observation made during the above tests showed that a spray touch-up treatment using a conventional solution improved the protection of aged or abraded coatings.

In order to provide satisfactory corrosion protection to the Saturn V vehicle, it was recommended that all conversion coatings which have been subjected to weld heat be repaired for a distance of at least 6 inches from the weld. Techniques which include mechanical stripping and manual application of the coating solution should be employed. In addition, completed tank assemblies should receive a spray touch-up treatment to insure adequate corrosion protection to the 2219-T87 aluminum alloy (FIG 14).

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"Chromate Conversion Coatings for," by C. W. Ostrander, Materials in Design Engineering, August 1960, pages 116-120.

TABLE I

COATING REPAIR METHODS AND RESULTS

	Surface Treatment	Coating Treatment	Salt Spray Results 24 Hours	Salt Spray Results 168 Hours	Rating
1.	Blank - No Heat	Regular	No Change	Very Mild Corrosion	A
2.	Acetone Wipe	None	Moderate Corrosion	Considerable	D
3.	Acetone Scrub	5 Min Immersion*	Mild	Moderate	C
4.	Brush Deoxidizer, 5 Min Mil-M-10578 (H_3PO_4)	5 Min Immersion	Mild	Moderate	C+
5.	As Above, CrO_4 Deoxidizer	5 Min Immersion	Mild	Moderate	C+
6.	Power Brushed (Cres)	5 Min Immersion	No Change	Very Mild	A
7.	As Above	5 Min Brush	No Change	Very Mild	A
8.	Solvent Brushed	Sprayed, Iridite Sol. + Thickening Agent 5 Min	Mild	Moderate	C
9.	Solvent & Power Brushed (Cres)	As Above	No Change	Very Mild	A
10.	Solvent Brushed	Brushed 5 Min	Mild	Moderate	C-
11.	See 4	Brushed Iridite 2 1/4 oz/gal 10 Min	Very Mild	Mild-Moderate	B
12.	Cres. Wool Scrubbed	As Above	No Corrosion	Very Mild	A
13.	Solvent Brushed	As Above	Mild	Moderate	C+
14.	Warm Detergent Sprayed 10 Min Rinse	Sprayed 5 Min	Mild	Mild-Moderate	B
15.	Scotch Brite Scrubbed	Brushed as 11	No Corrosion	Very Mild	A
16.	Scotch Brite Scrubbed	Sprayed 5 Min	No Corrosion	Very Mild	A

*Iridite 14-2, 1-1/4 oz/gal Except as Noted

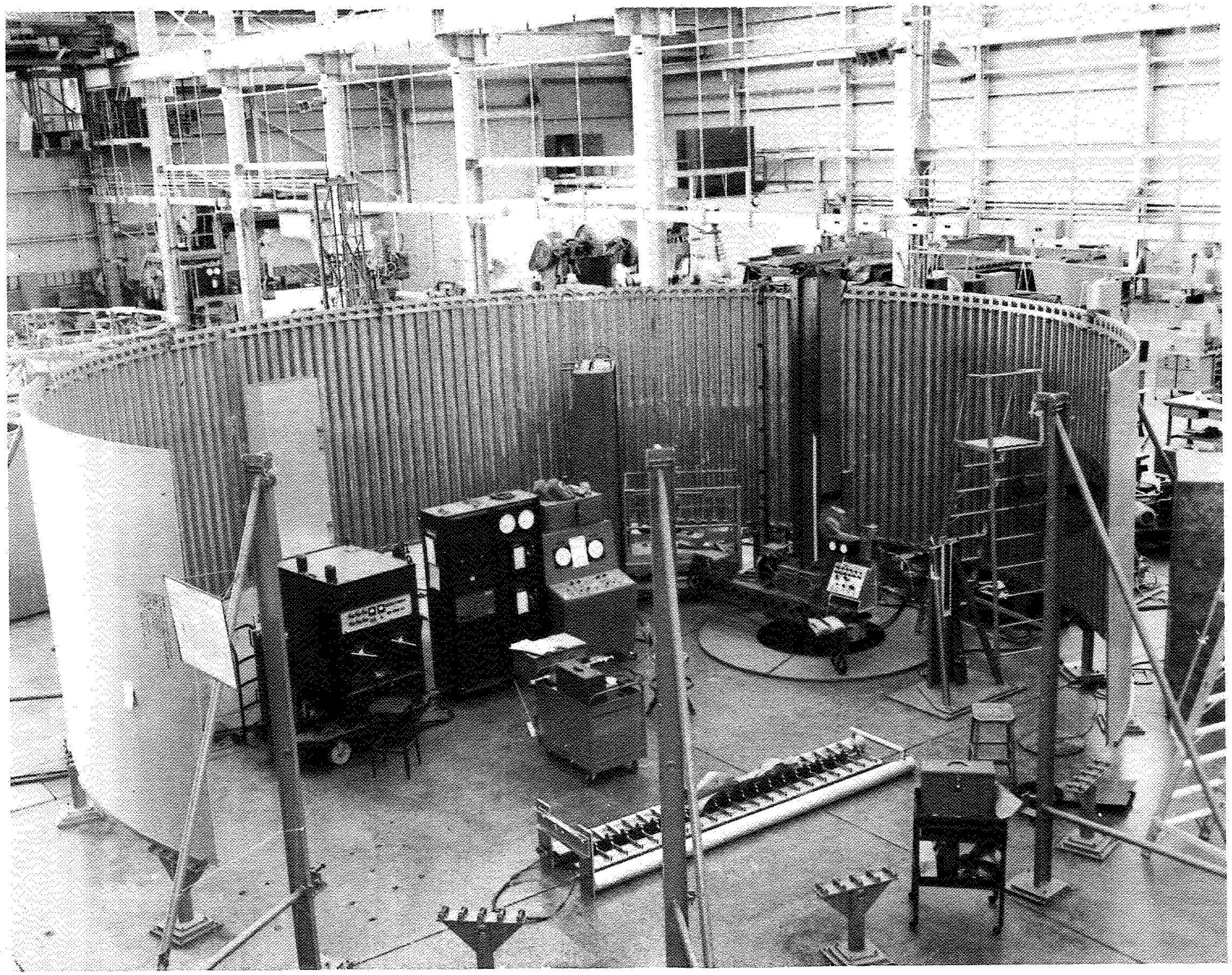

FIGURE 1 - Assembly of Saturn S-IC Tank Skin

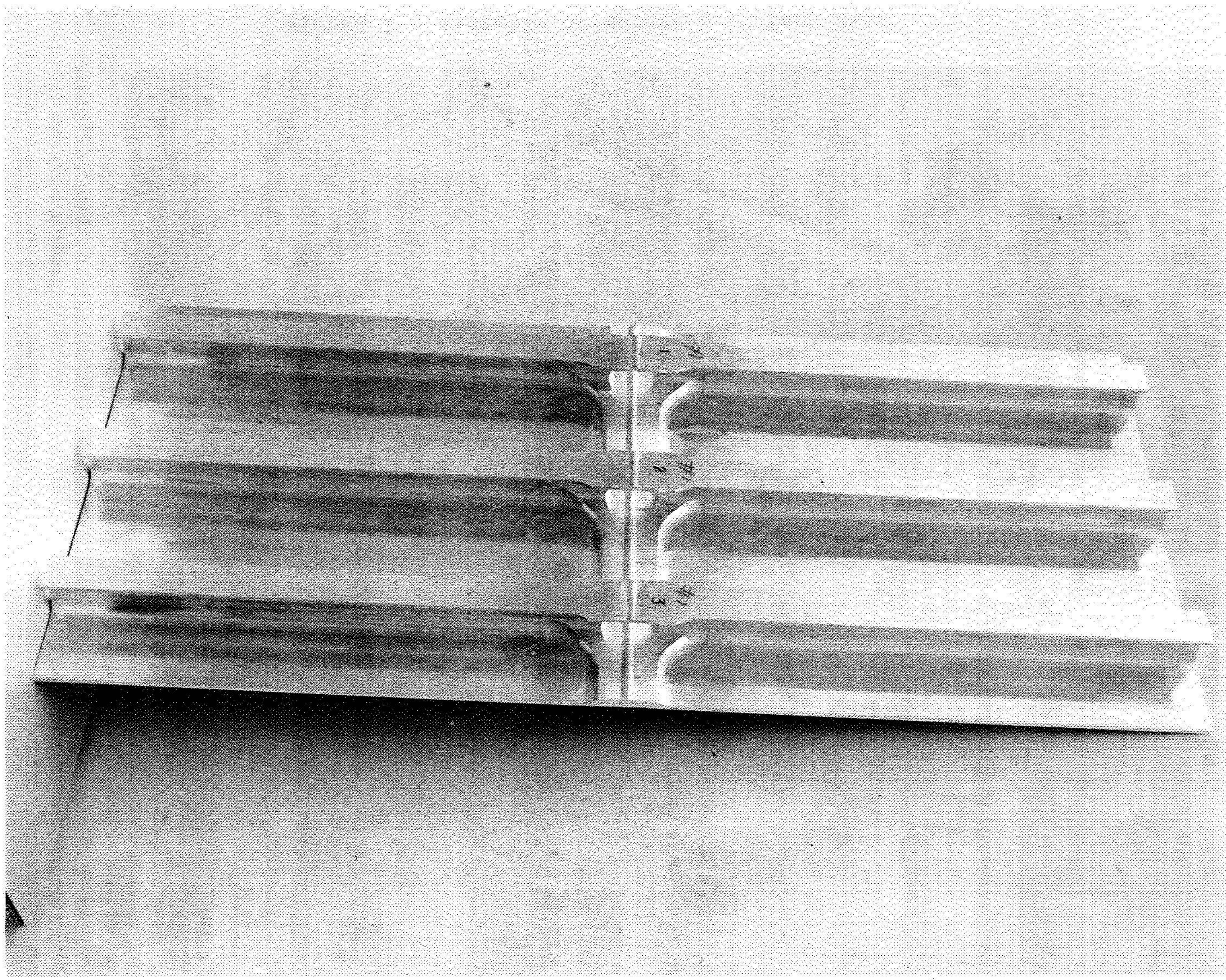

FIGURE 2 - Skin Section Showing T- Stiffener Configuration

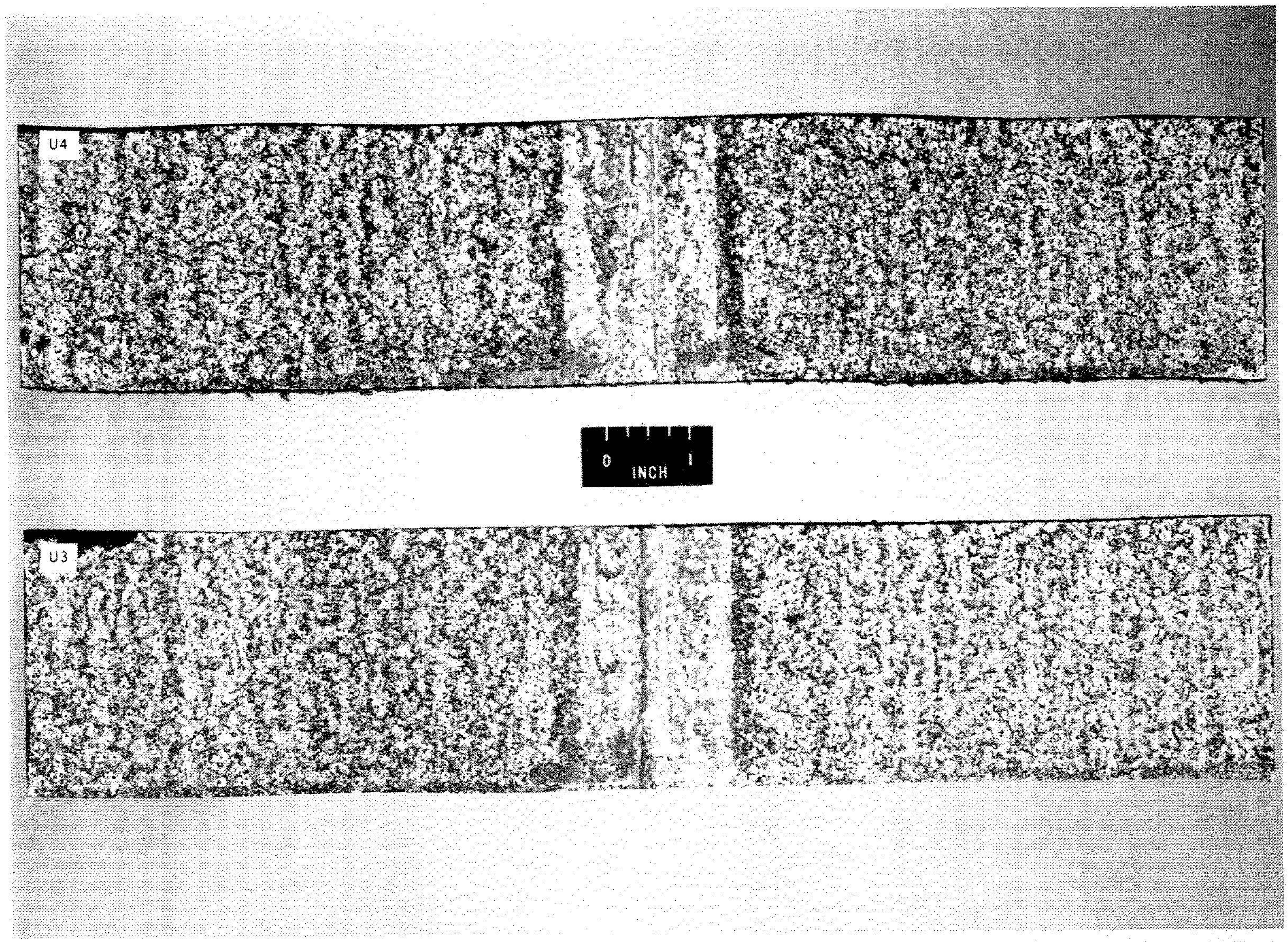

FIGURE 3 - Conversion Coated Before Welding - 168 Hours Salt Spray

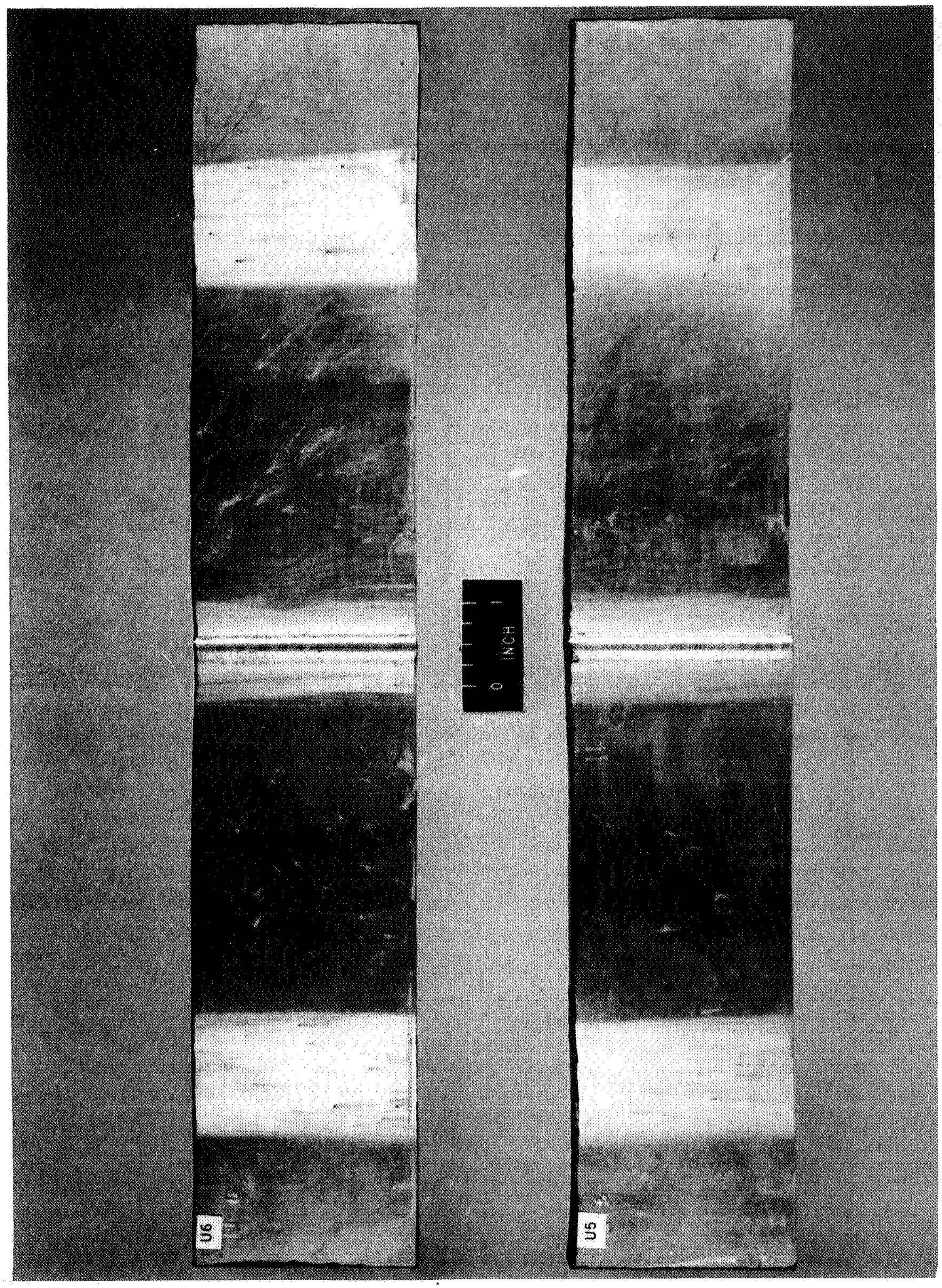

FIGURE 4 - Conversion Coated After Welding - 168 Hours Salt Spray

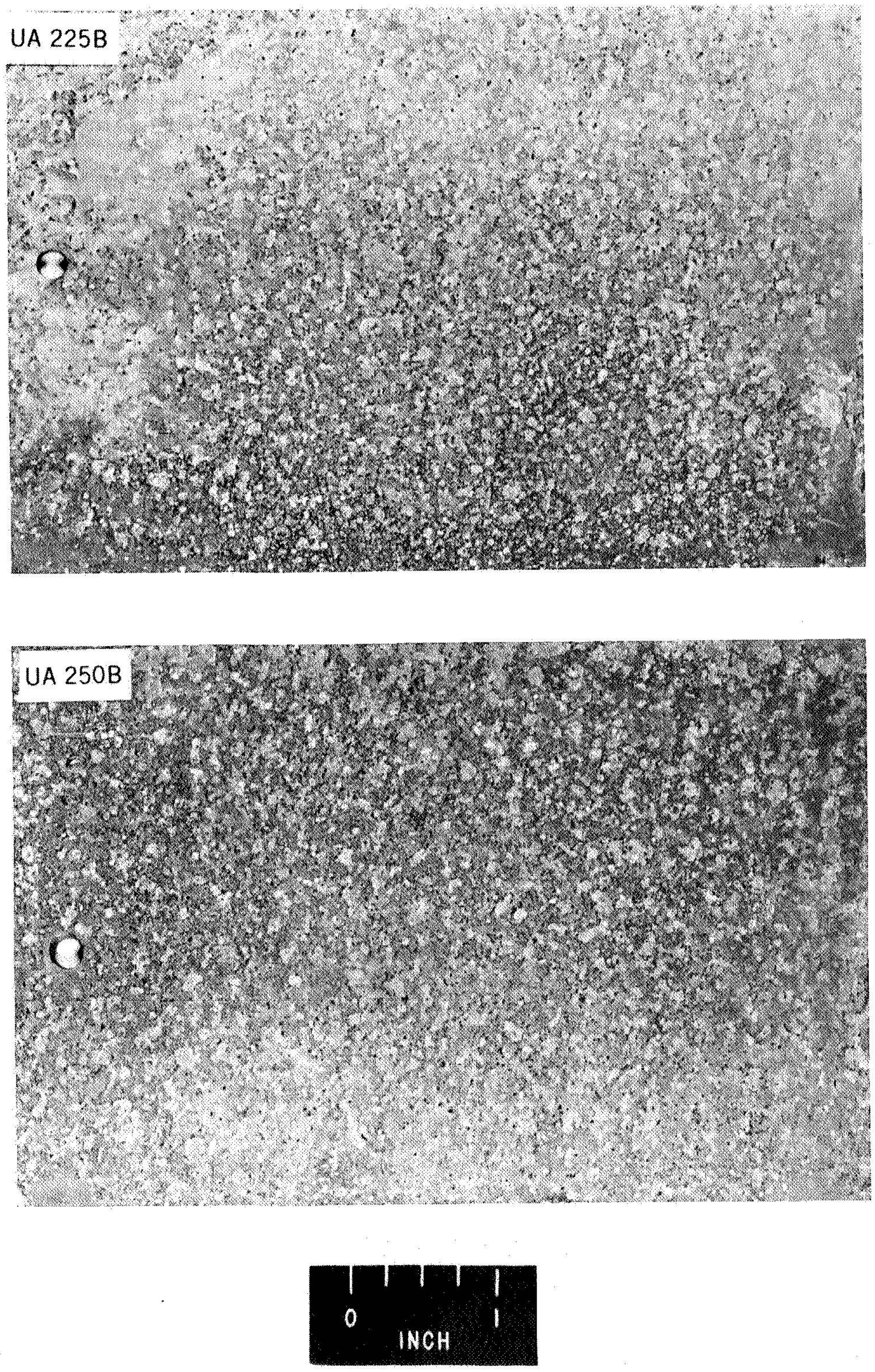

FIGURE 5 - Conversion Coated Panels Exposed to 180°F, (Above) and 200°F (below) 24 Hours Salt Spray

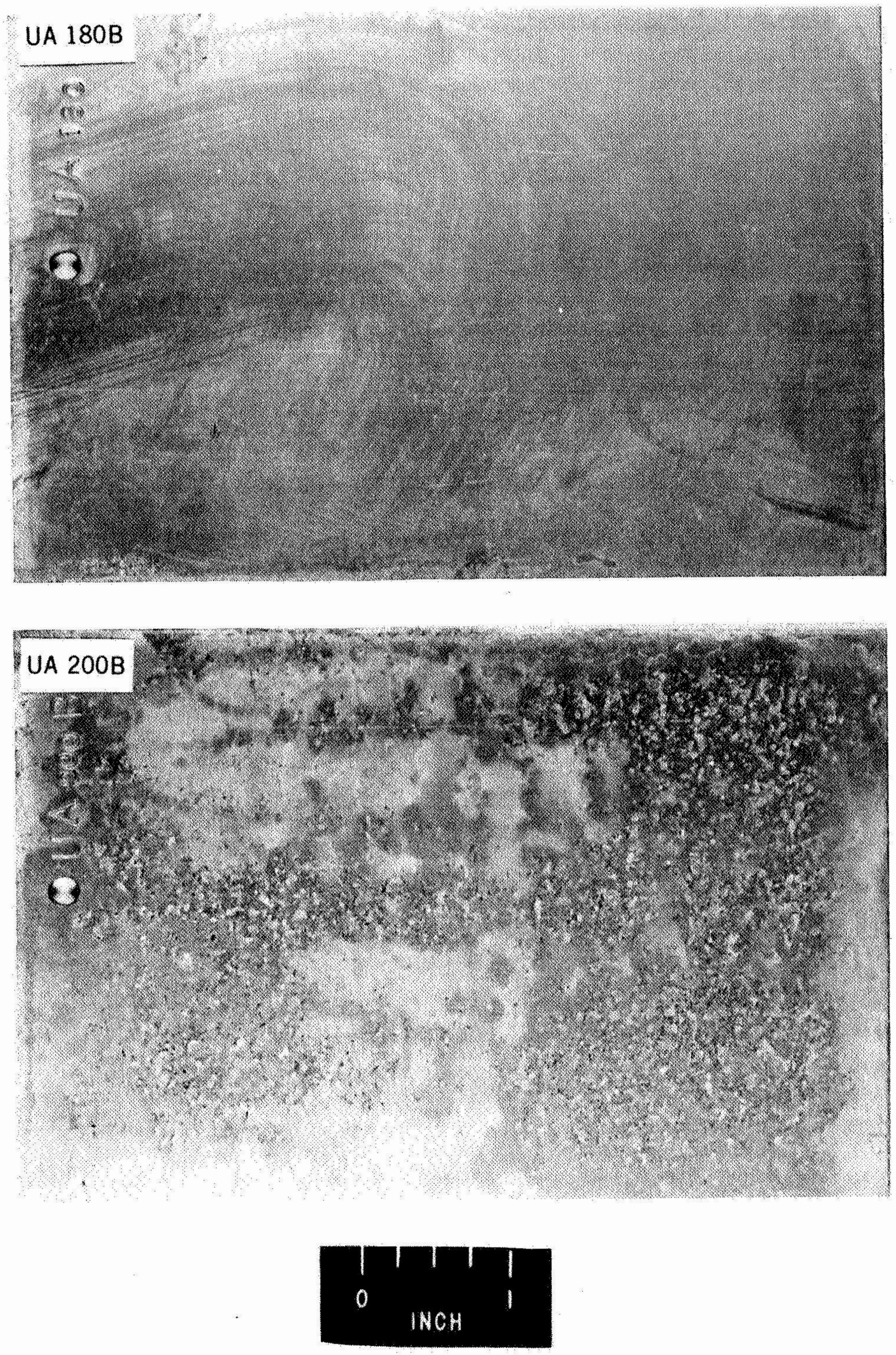

FIGURE 6 - Conversion Coated Panels Exposed to 140°F (above) and 160°F (below) 24 Hours Salt Spray

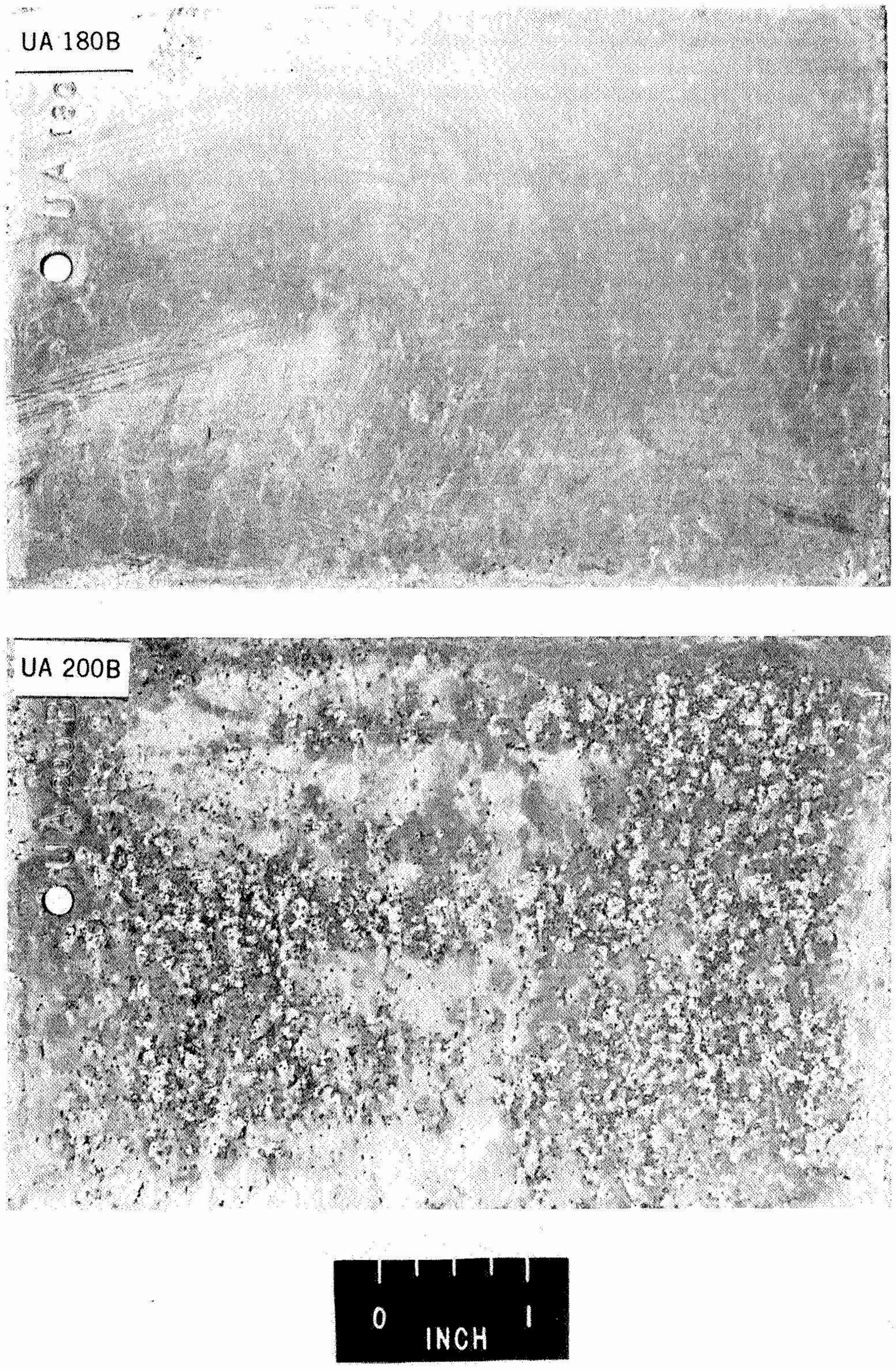

FIGURE 7 - Conversion Coated Panels Exposed to 140°F (above) and 160°F (below) 72 Hours Salt Spray

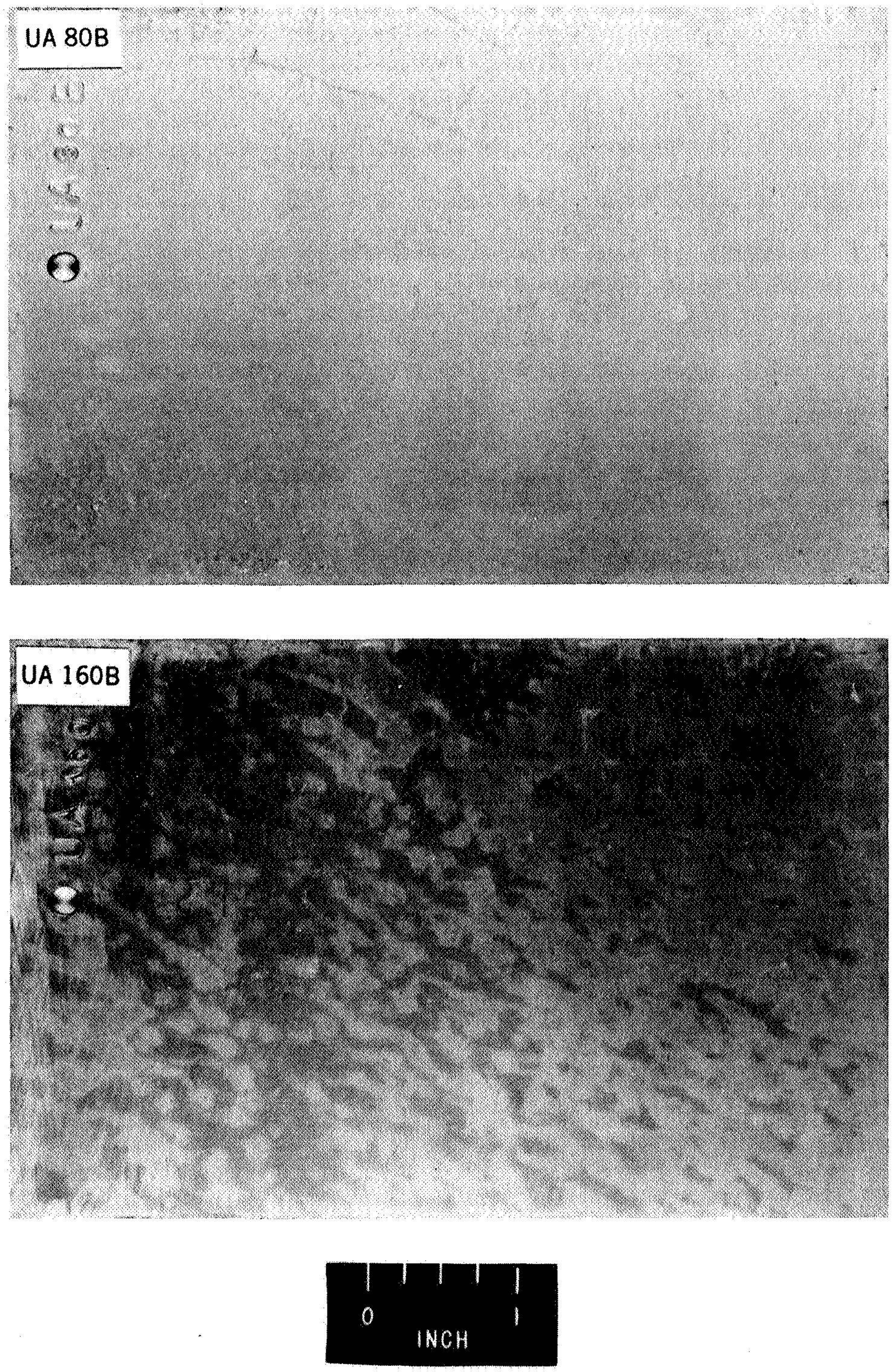

FIGURE 8 - Conversion Coated Panels Exposed to 80°F (above) and 120°F (below) 24 Hours Salt Spray

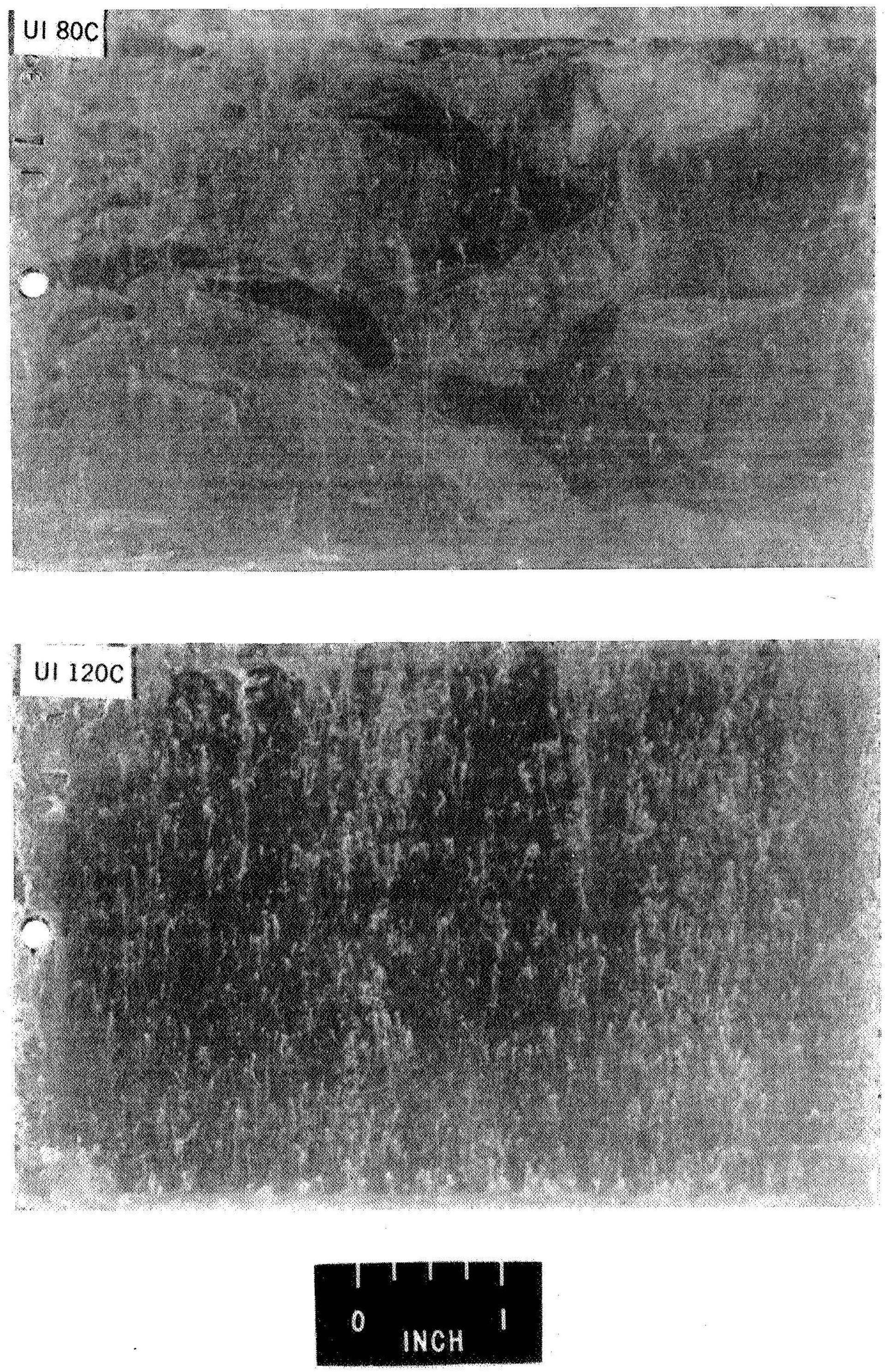

FIGURE 9 - Conversion Coated Panels Exposed to 80°F (above) and 120°F (below) 168 Hours Salt Spray

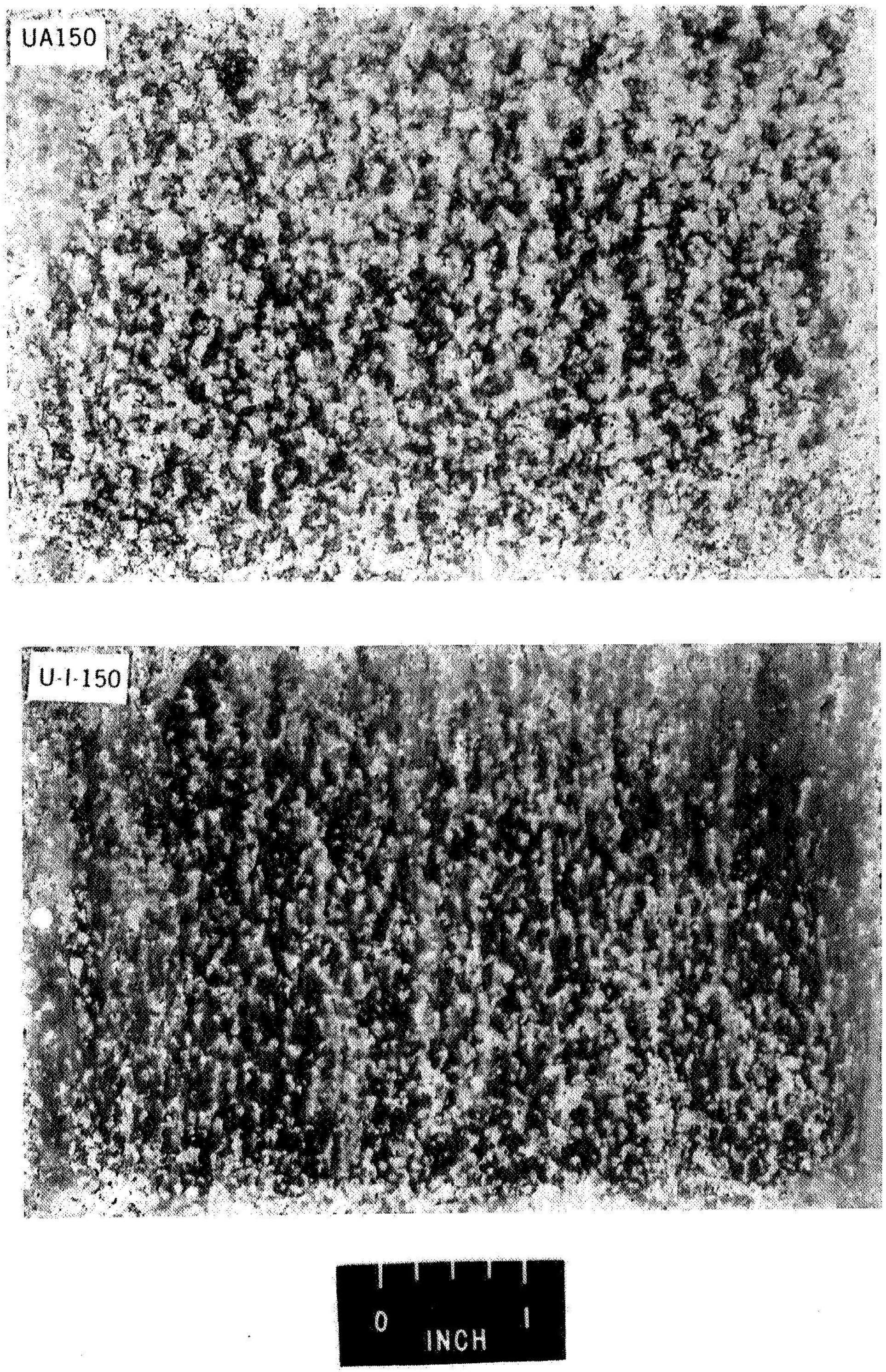

FIGURE 10 - Two Different Conversion Coatings Exposed to 150°F for two Hours - 168 Hours Salt Spray

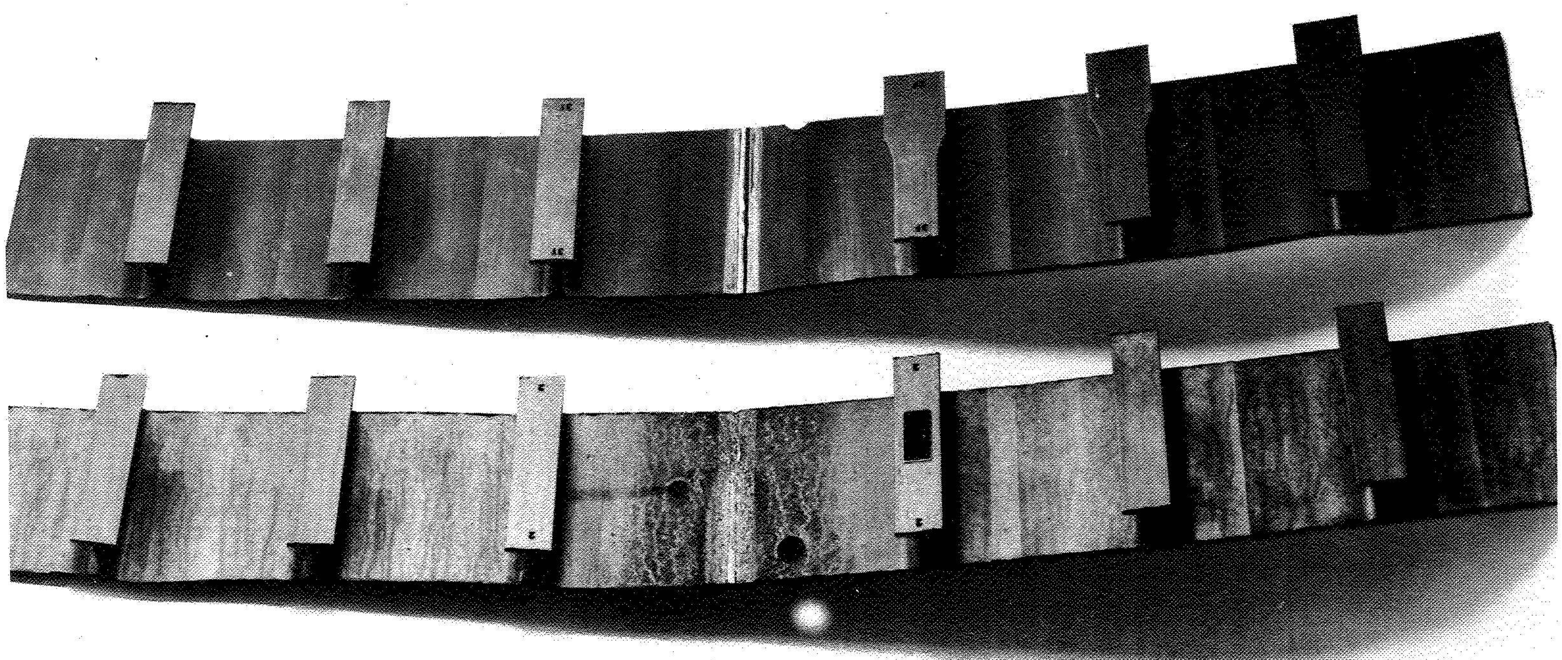

FIGURE 11 - Welded Configuration Section 0.23 Inch Thick, with and Without touch-up Treatment - 24 Hours Salt Spray

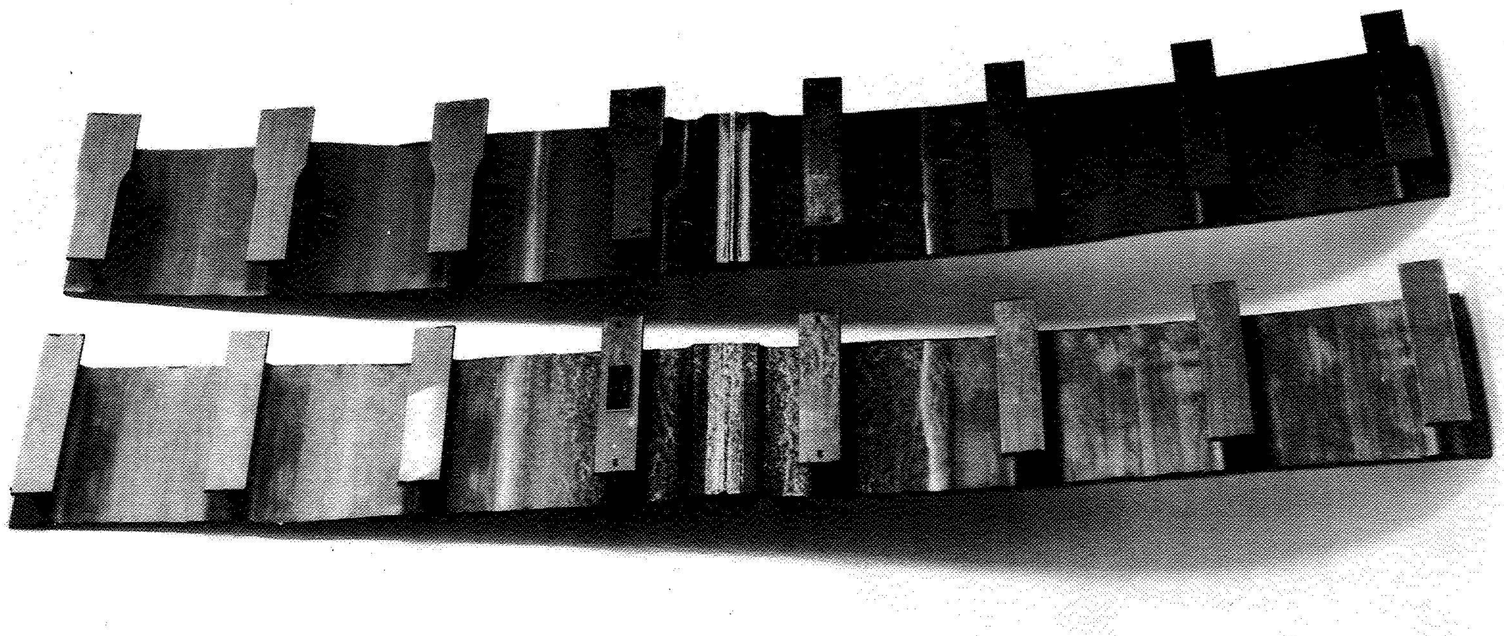

FIGURE 12 - Welded Configuration Section 0.5 Inch Thick Weld, With and Without Touch-up Treatment - 24 Hours Salt Spray

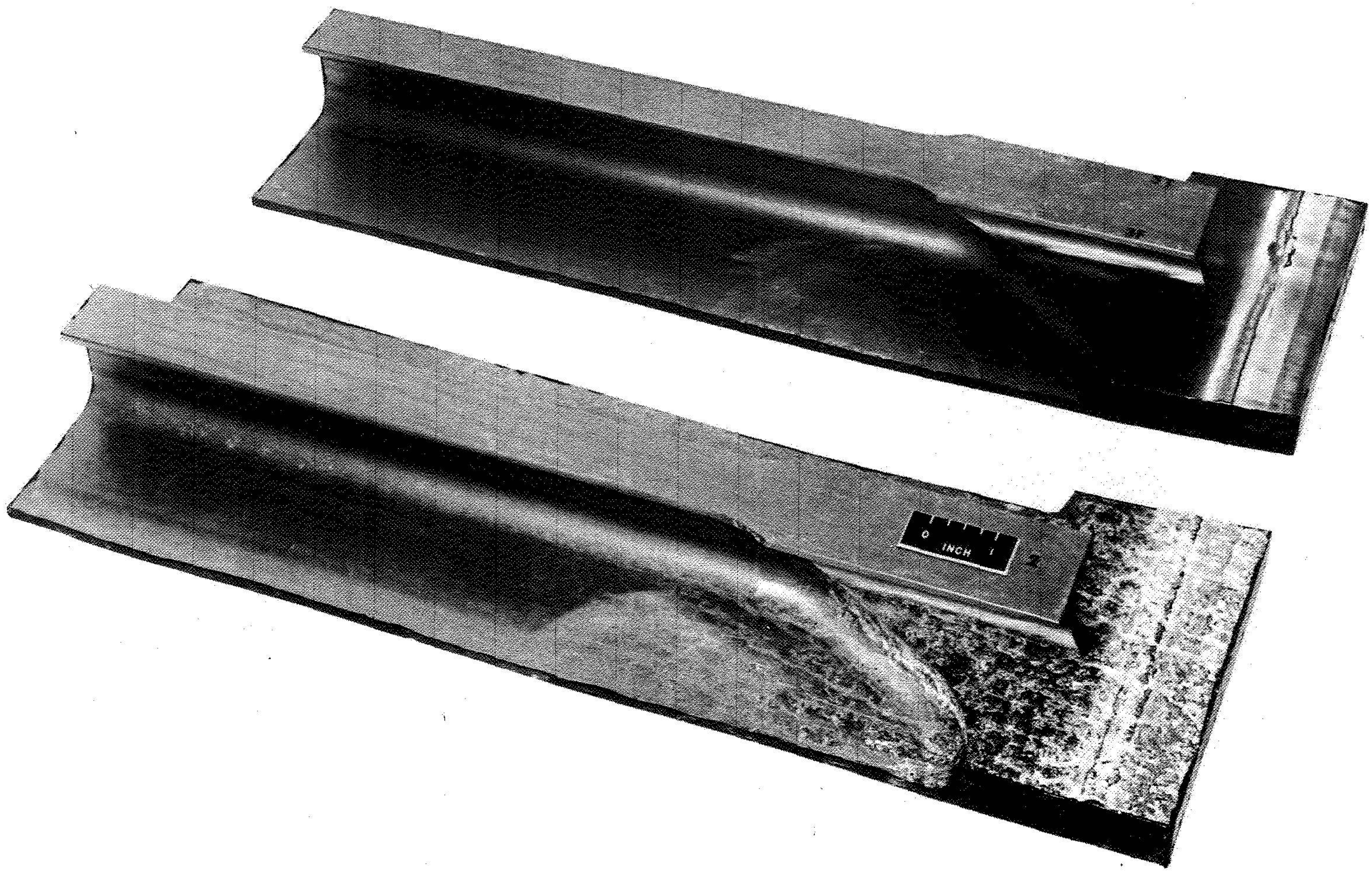

FIGURE 13 - Welded Configuration Section 0.87 Inch Thick Weld, With and Without Touch-up Treatment - 24 Hours Salt Spray

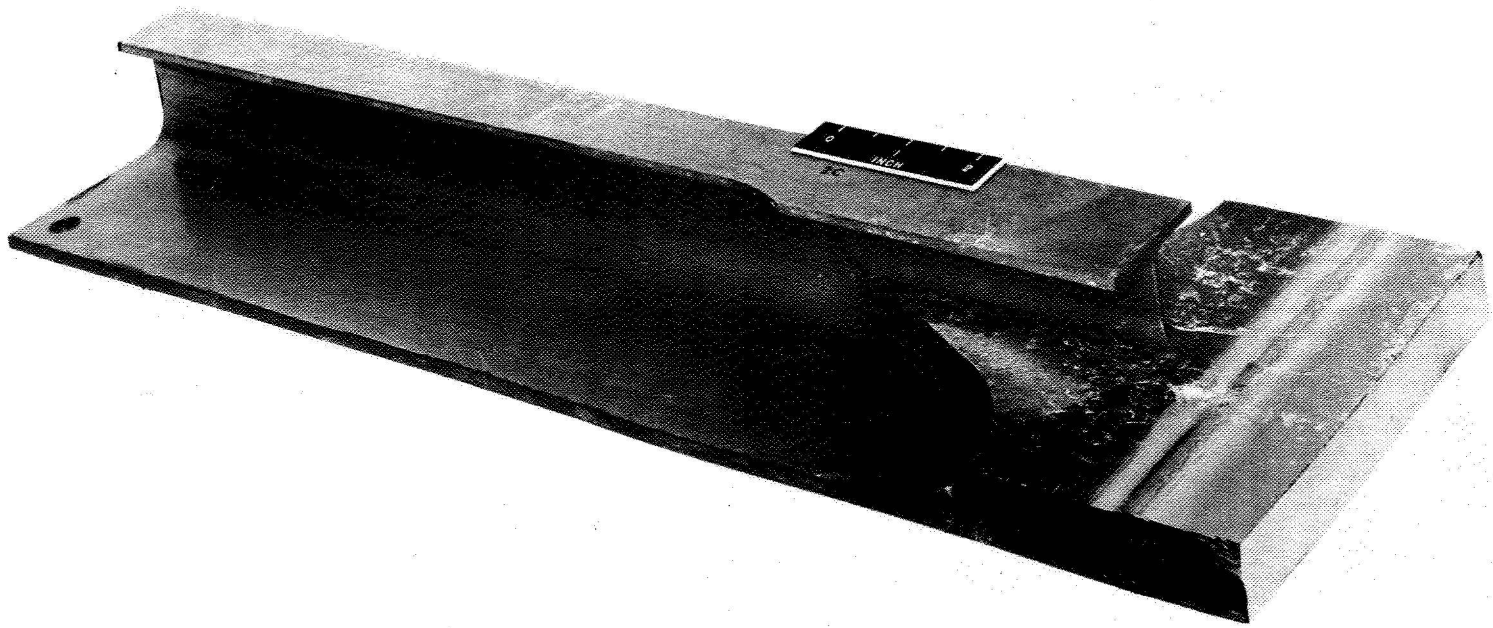

FIGURE 14 - Welded Configuration Section 0.87 Inch Thick Weld, Conversion Coated, Welded, and Received a Touch-up Treatment During a Saturn Fuel Tank Processing - 24 Hours Salt Spray

January 3, 1969 NASA TM X-53808

APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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